Robotic and EVA/Robotic Servicing: Past Experiences, Future Promise

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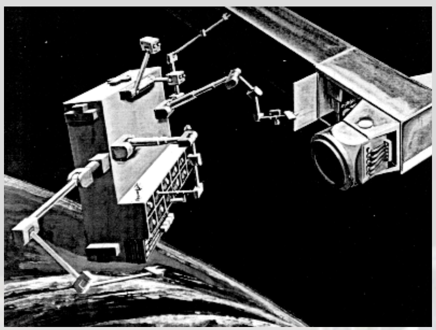
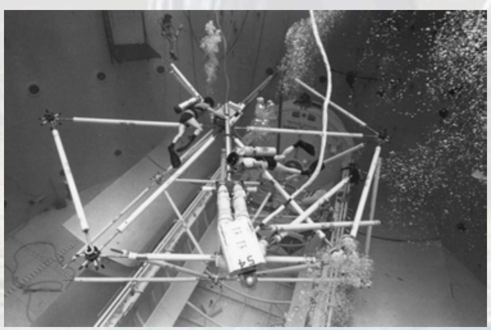
SSL Robotics/Servicing Timeline (80's)

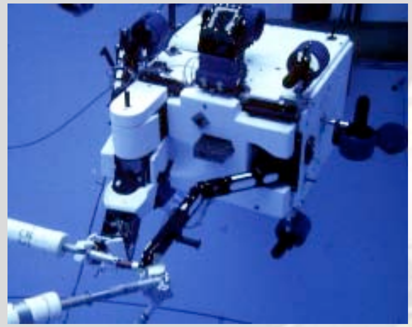
'80 '81 '82 '83 '84 '85 '86 '87 '88 '89

SSL studies applications of automation, robotics, and machine intelligence for servicing Hubble and other Great Observatories for NASA MSFC



Robot-aided EVA structural assembly





Initial operational tests of Beam Assembly Teleoperator

Experimental Assembly of Structures in EVA flies on STS 61-B

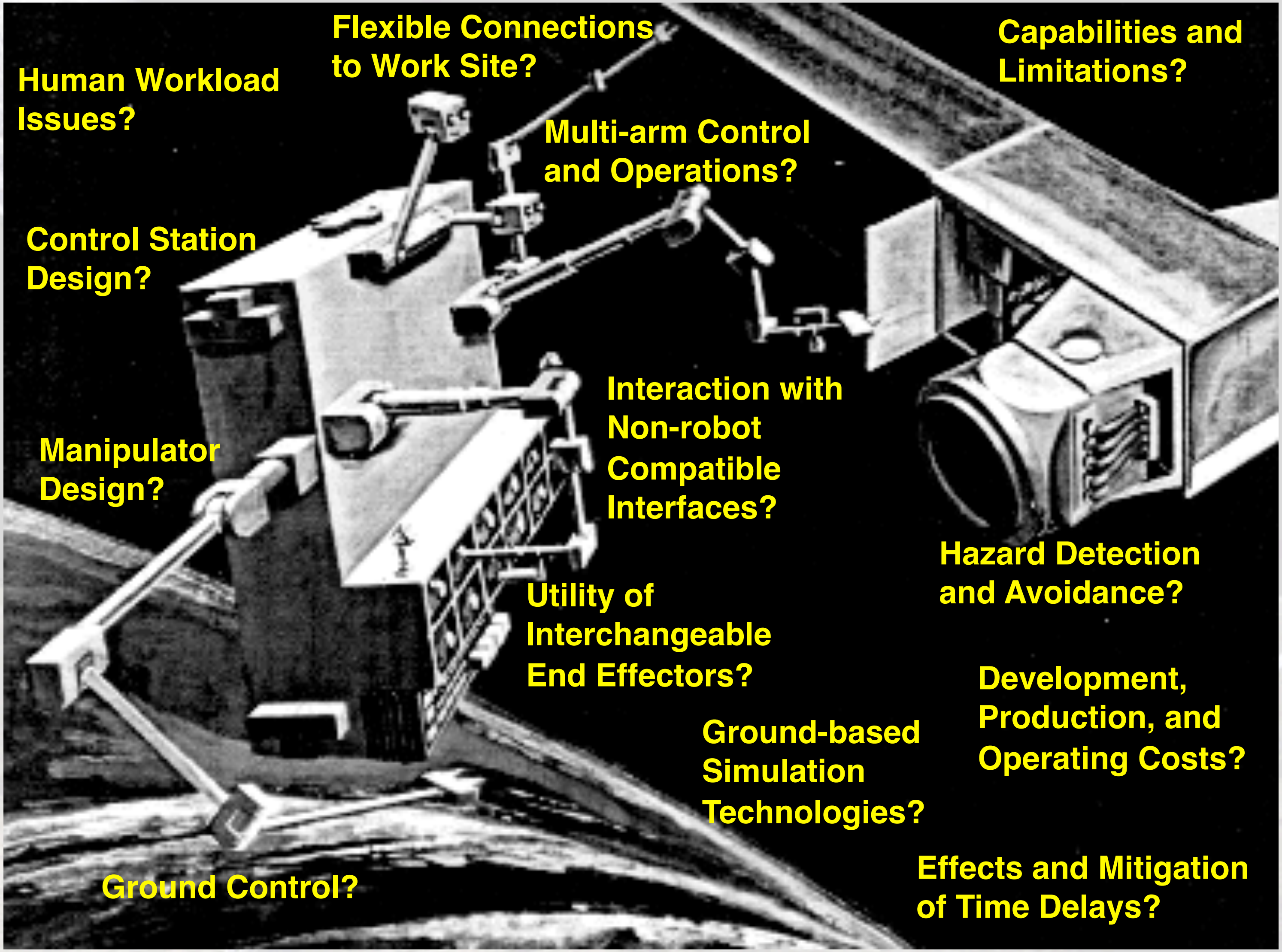
BAT used for extensive servicing tests on HST training mockup

SSL develops ParaShield flight test vehicle for suborbital mission

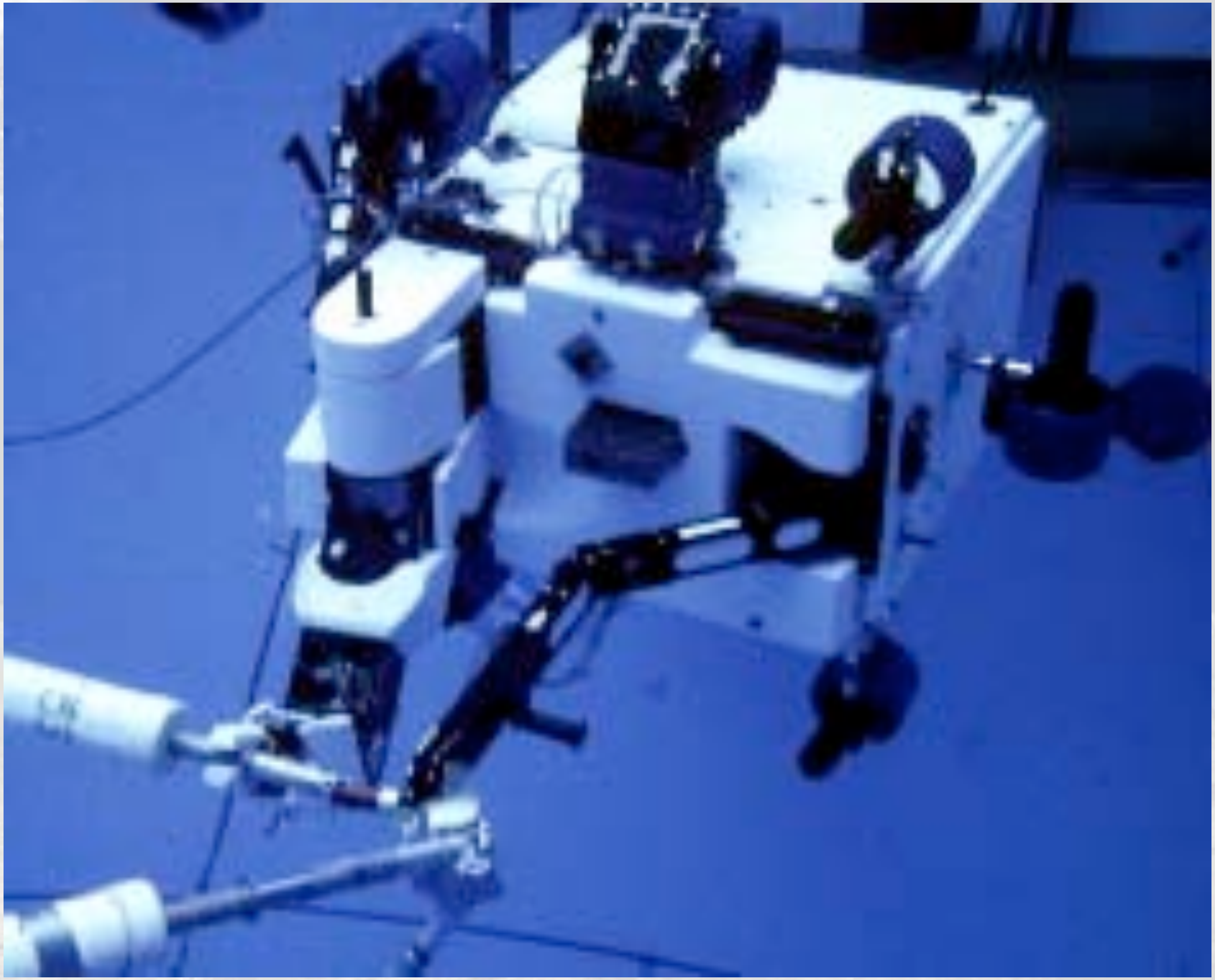
ARAMIS Telerobotics Study (1980)

- **Survey of five NASA "Great Observatories" to assess impacts and benefits of telerobotic servicing - major results:**
- **Ground-controlled telerobotics is a pivotal technology for future space operations**
- **Robotic system should be designed to perform EVA-equivalent tasks using EVA interfaces**
  - **Maximum market penetration for robot**
  - **Maximum operational reliability**
  - **Designing to EVA standards well understood**
- **Fully capable robotic system needs to be able to do rendezvous and proximity operations, grapple, dexterous manipulation**

Fundamental Issues in Robotic Servicing



Beam Assembly Teleoperator



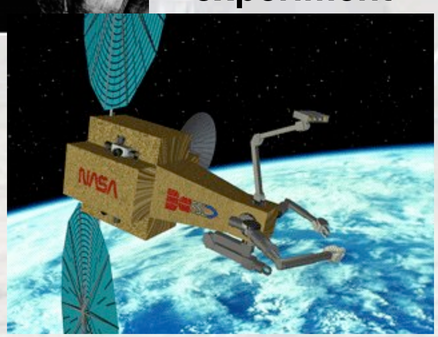
SSL Robotics/Servicing Timeline (90's)

'90 '91 '92 '93 '94 '95 '96 '97 '98 '99

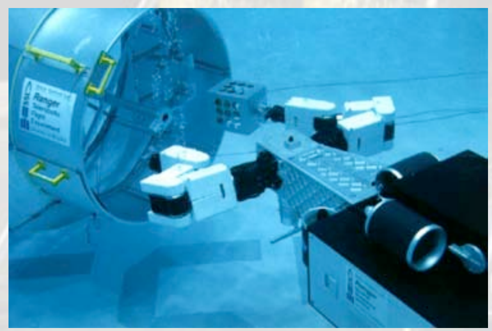
SSL designs Ranger based on experience with HST servicing

UMd NBRF opens

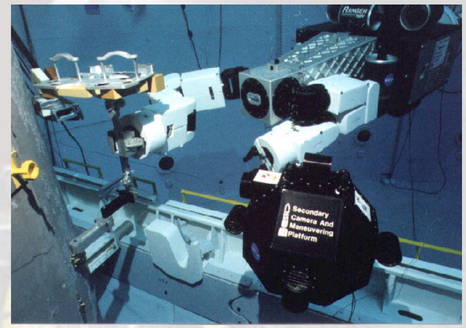
NASA selects Ranger TFX as low-cost robotic flight experiment



Ranger NBV operational



Ranger performs end-to-end HST servicing simulations



SSL directed to redesign Ranger for shuttle mission: Ranger TSX

Phase 0 PSRP

RTSX PDR

Phase 1 PSRP

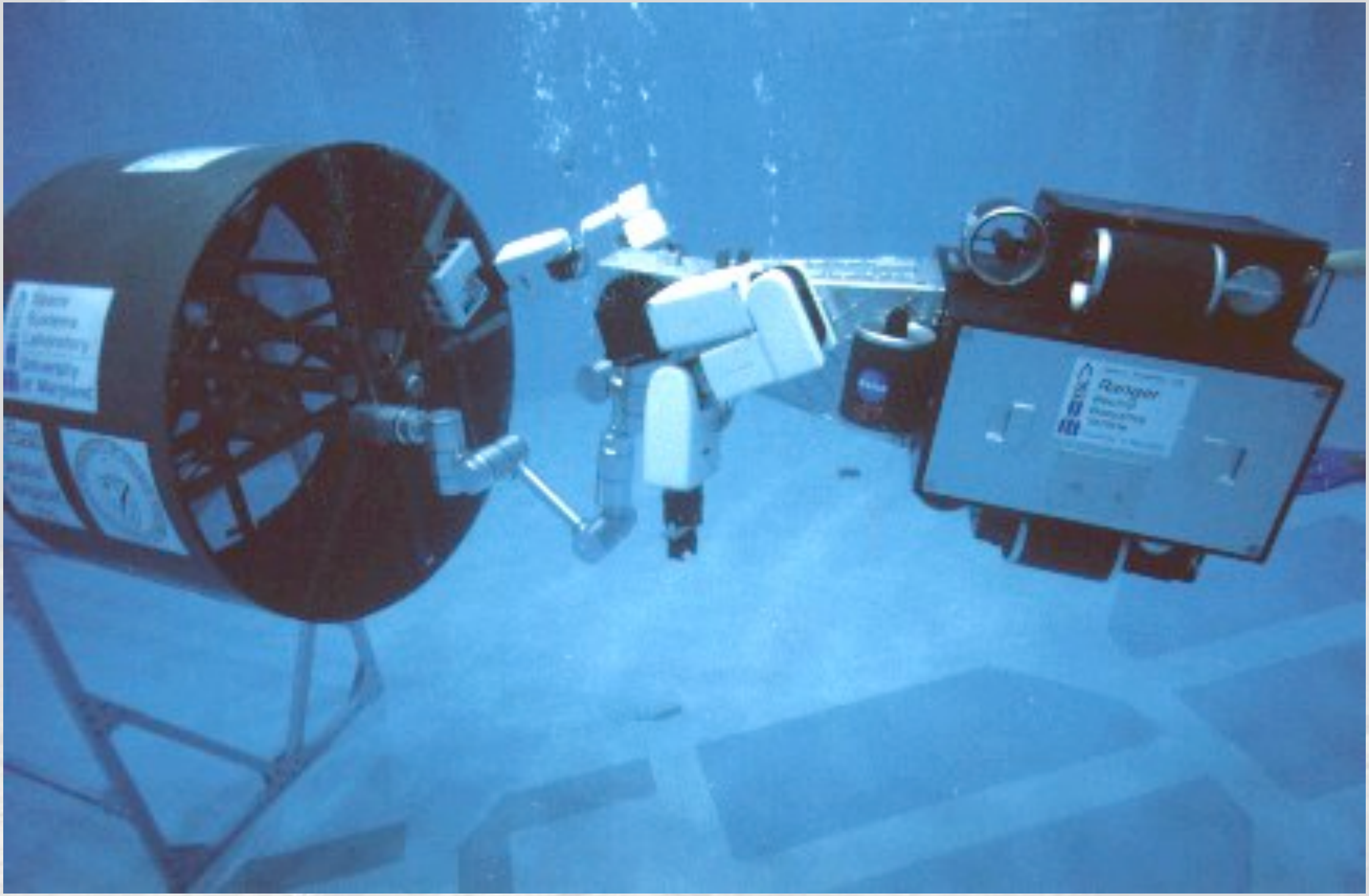
RTSX CDR

Phase 2 PSRP

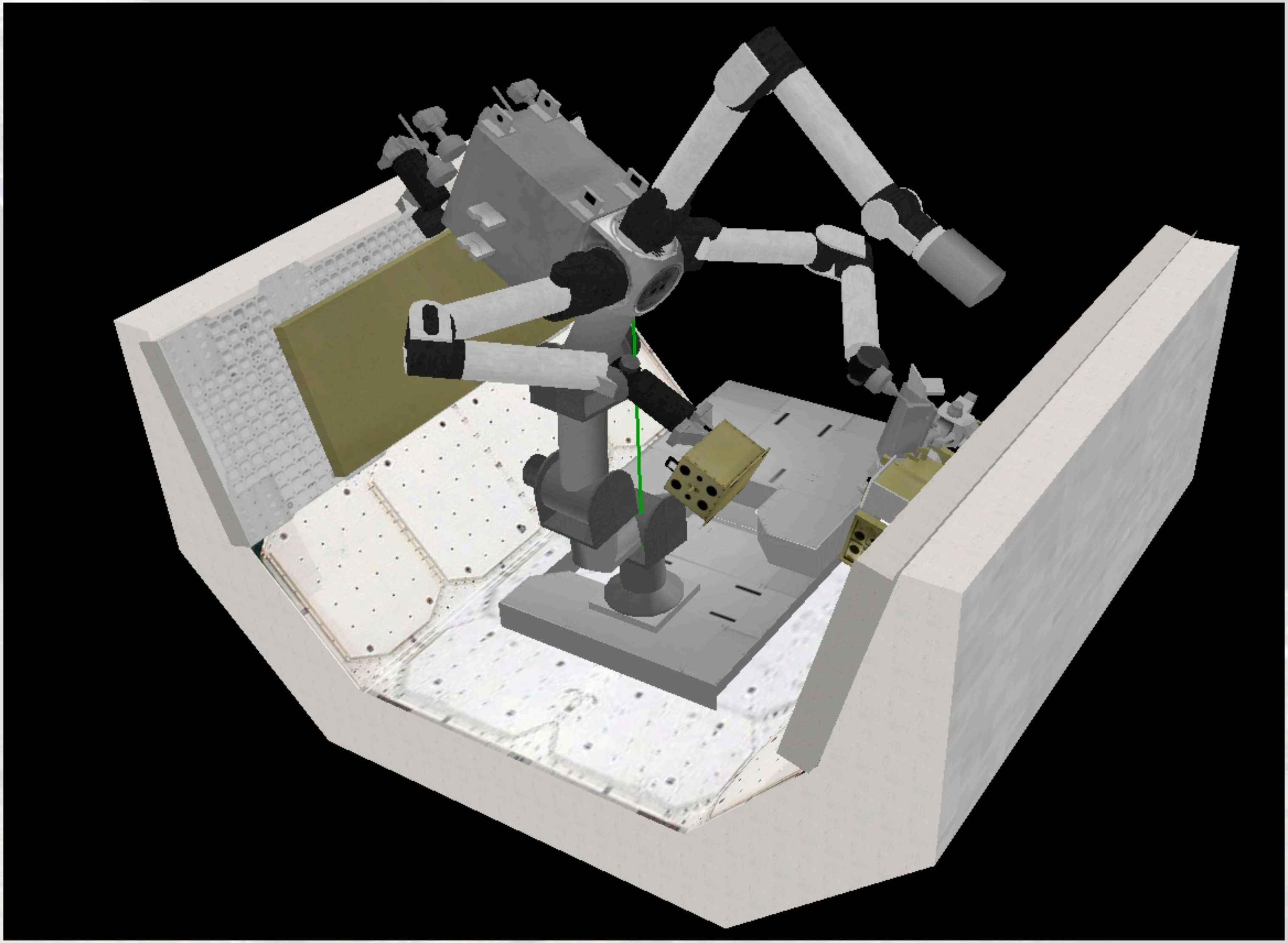
Environmental testing at JSC

Ranger Telerobotic Flight Experiment

Ranger Neutral Buoyancy Vehicle I



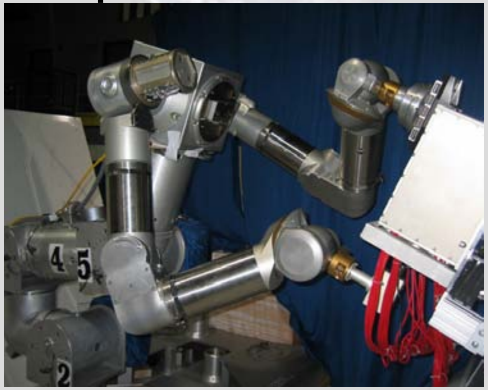
Ranger Telerobotic Shuttle Experiment



SSL Robotics/Servicing Timeline (00’s)

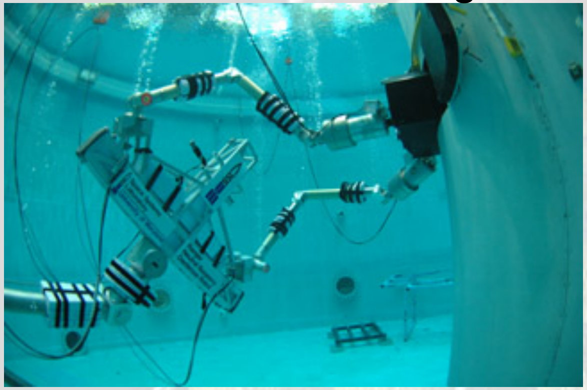
’00 ’01 ’02 ’03 ’04 ’05 ’06 ’07 ’08 ’09

Development of ECU operations timeline

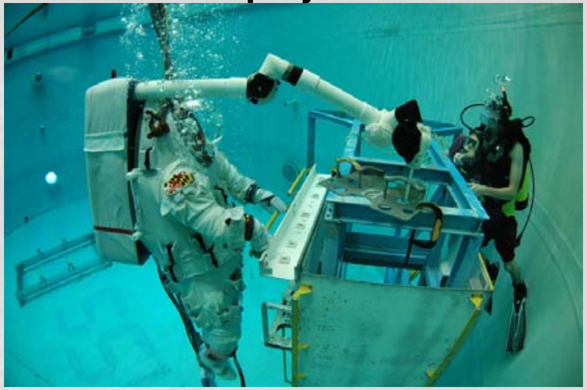


Ranger TSX program cancelled

Ranger simulates SPDM for GSFC HRSDM testing

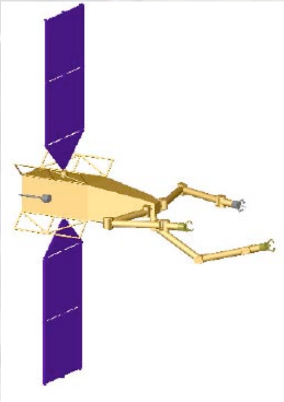


Suit-integrated manipulators, advanced displays and controls



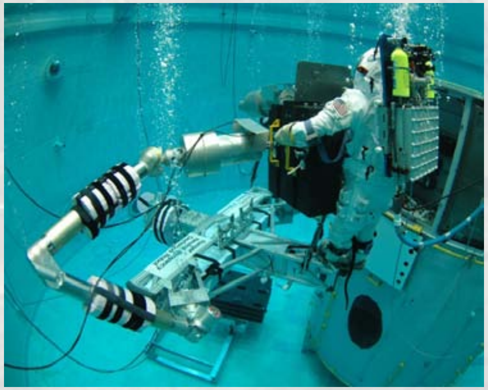
First tests of EVA/robot cooperation with Ranger

Modular miniature servicer development for DARPA



Ranger performs SUMO tasks at NRL

MX-2 suit operational; coop. EVA/robot servicing

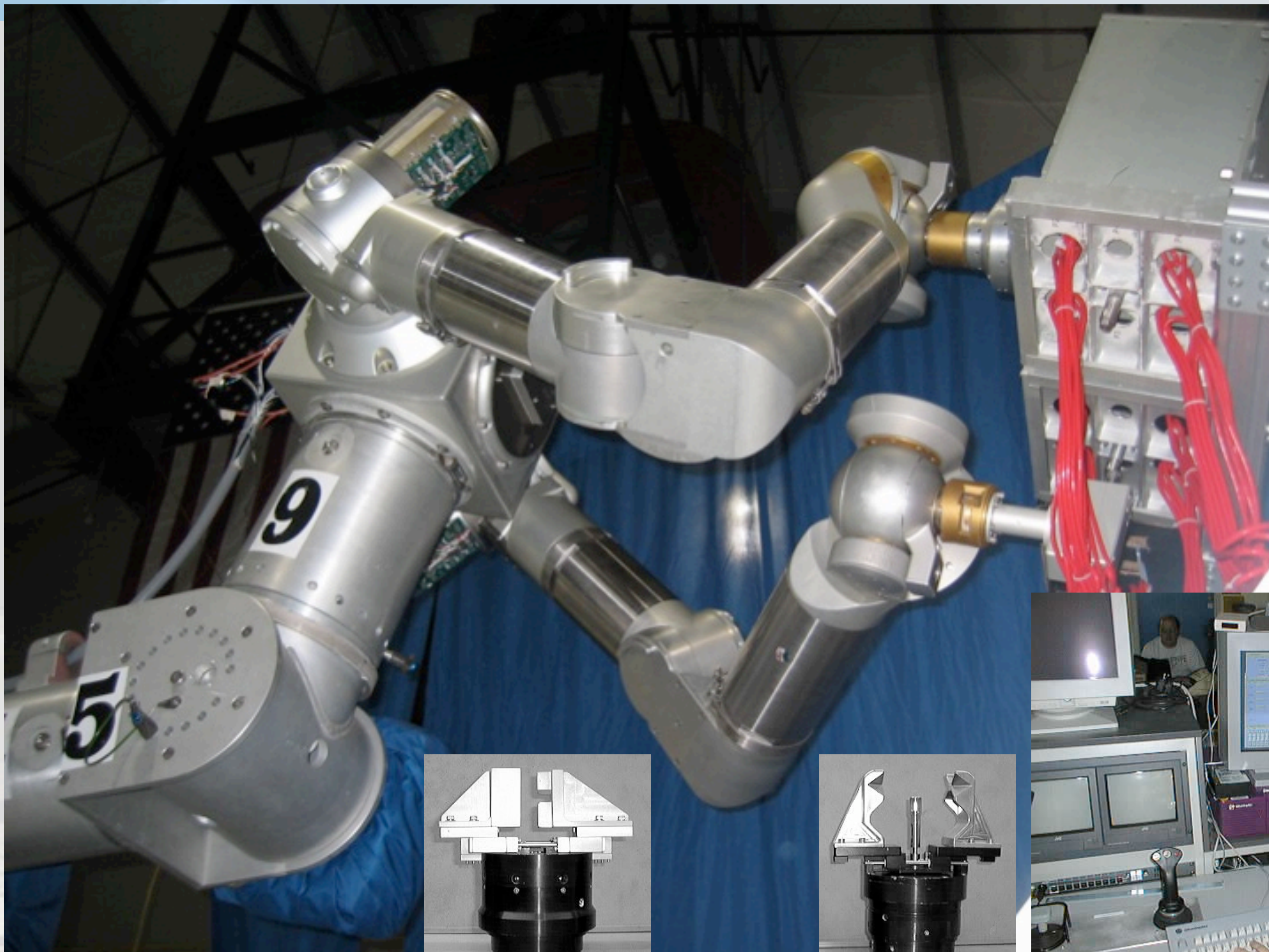


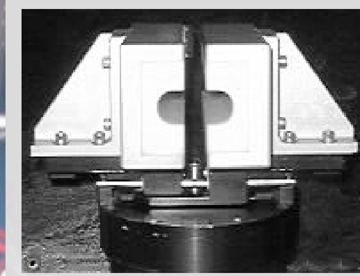
SAMURAI lightweight manipulator

UNIVERSITY OF MARYLAND

Space Systems Laboratory

Ranger Spacecraft Servicing System

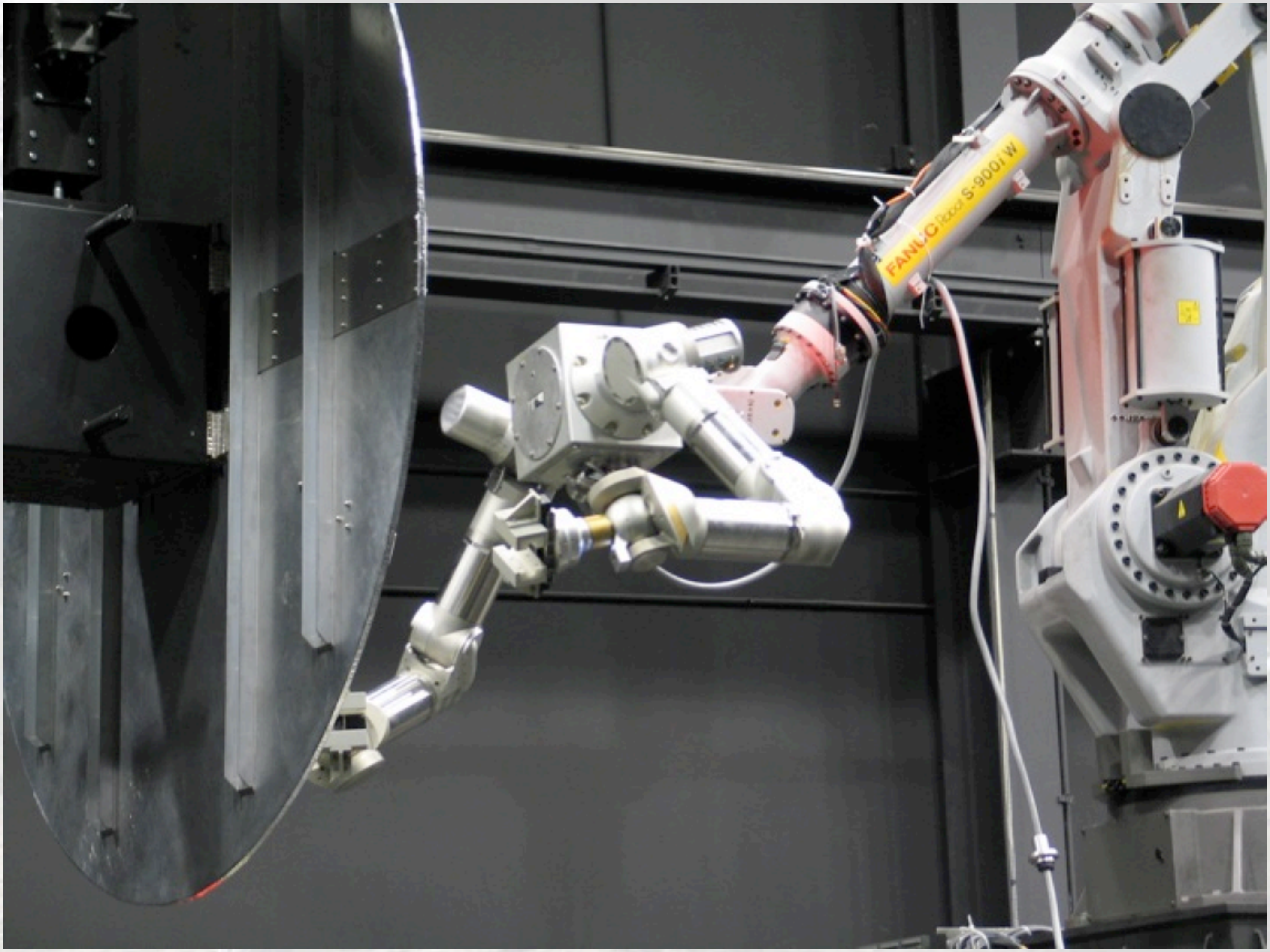




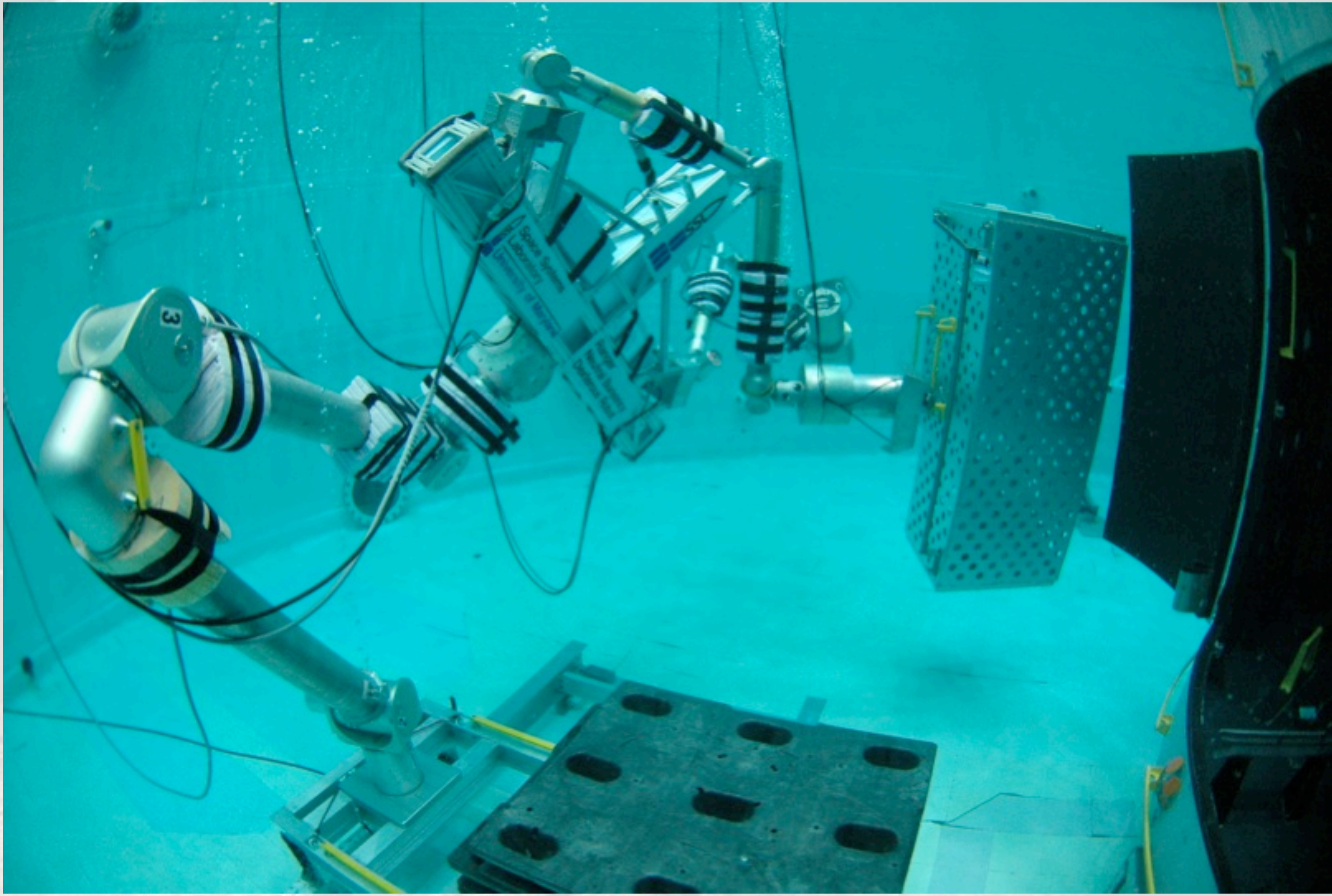
Ranger System Specifications

- Approximately EVA-glove-sized end effectors with 30 lbf force and 30 lb-ft torque capability in any direction
- Two human-scale arms with intersecting workspaces mounted on narrow base for restricted work sites
- High-bandwidth active compliance-control loop
- 8DOF allows autonomous obstacle and singularity avoidance
- Interchangeable end effector mechanism with two mechanical tool drives to each end effector
- Rad hardened MIL-STD-1553B distributed control architecture recognizes and safes errors in ≤ 30 msec
- 800,000 lines of code for nominal and contingency ops
- Flight-certified through NASA Phase 2 PSRP
- Operable in 1G, underwater, and space environments
- Advanced control station mitigates time delays ≤ 6 sec

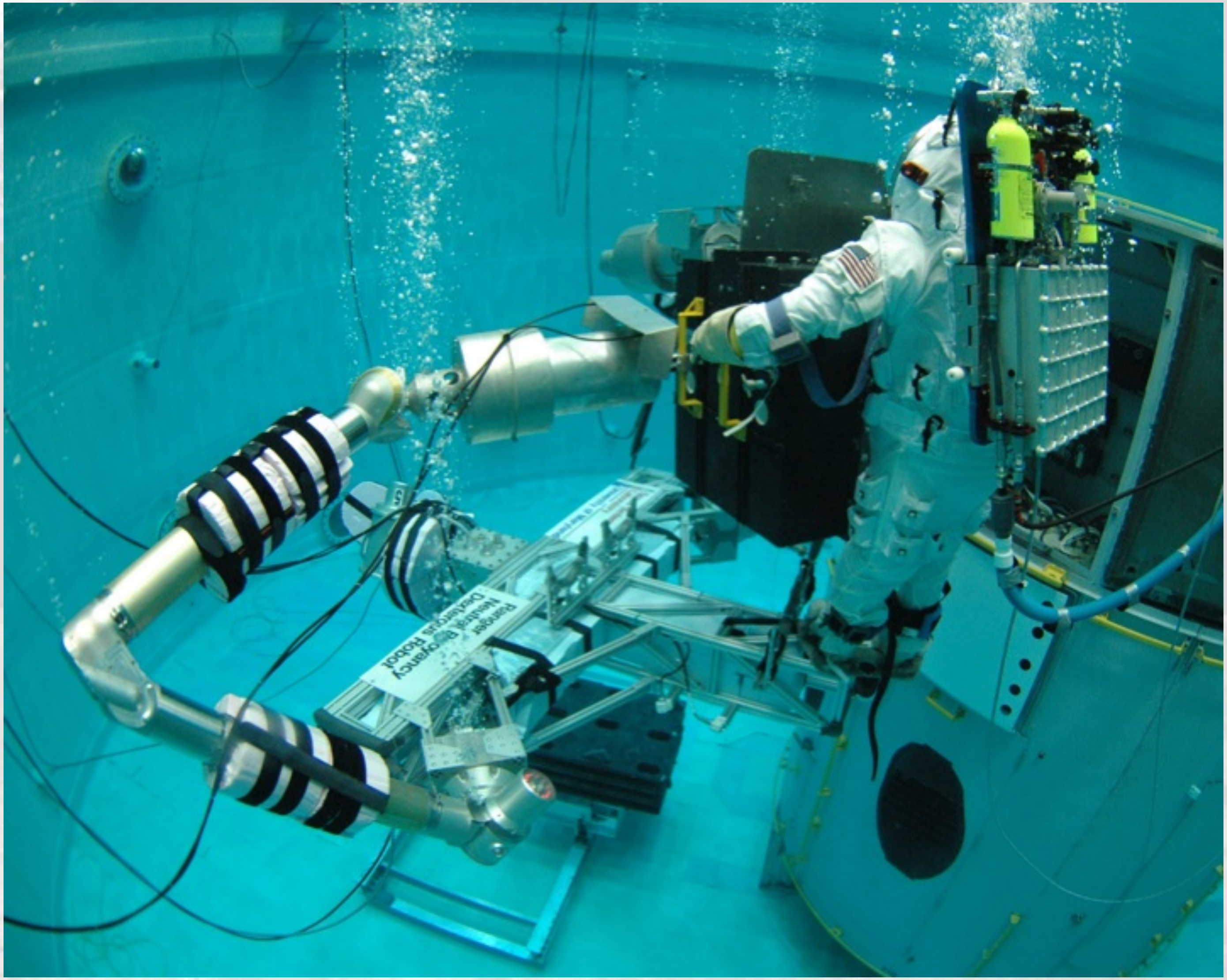
Ranger Arms for SUMO Grappling



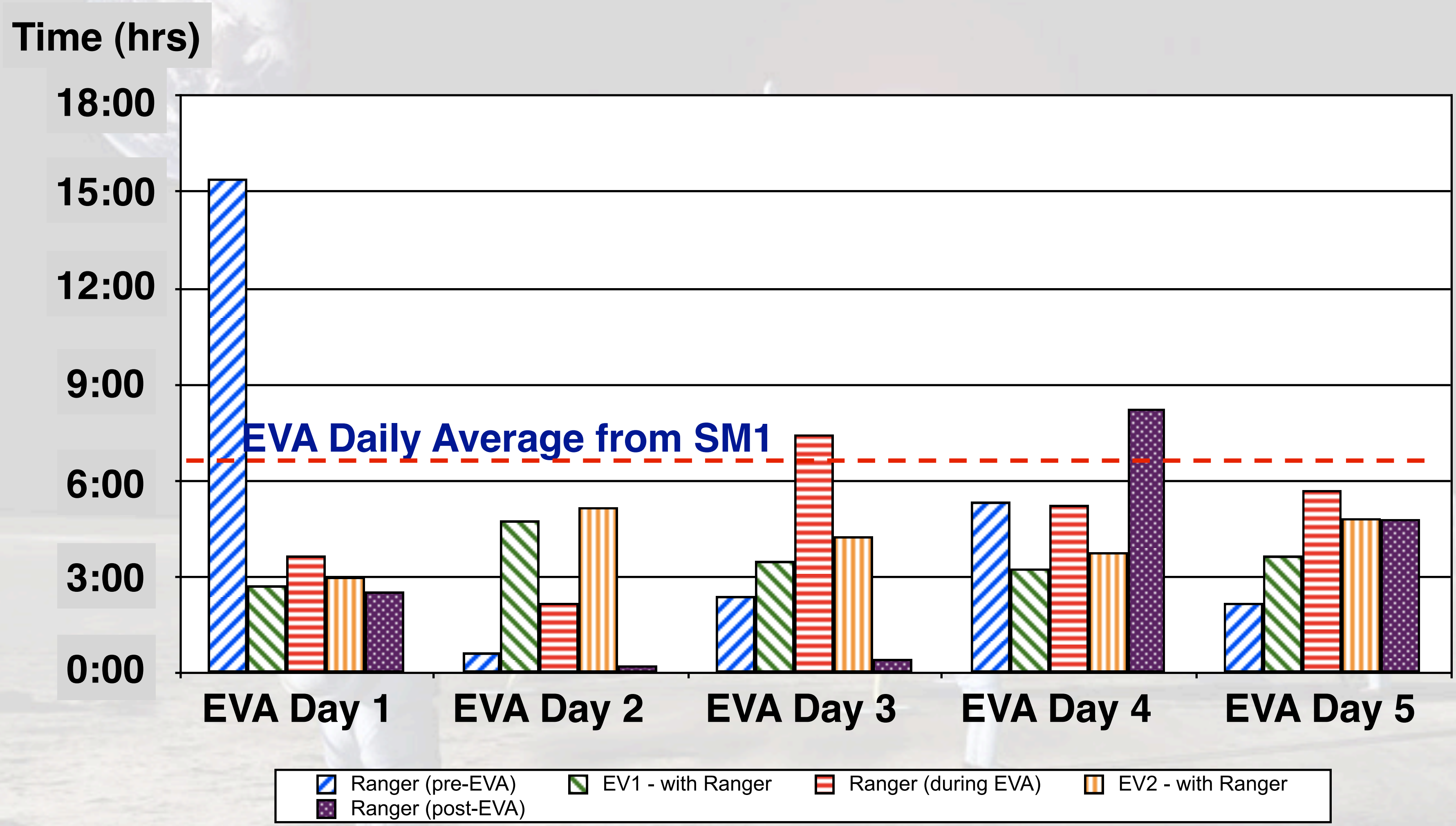
Ranger Performing HST AI Changeout



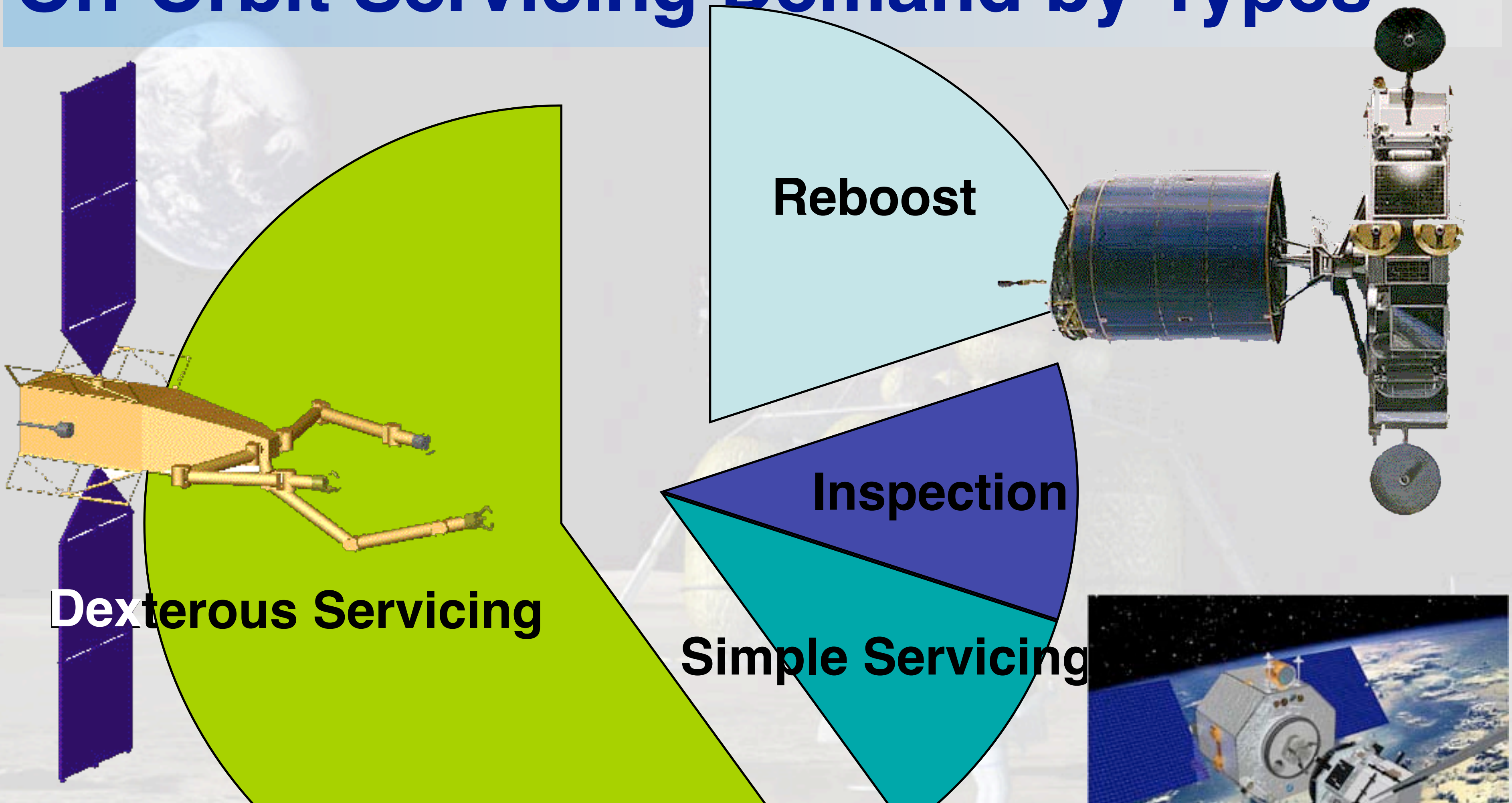
EVA/Robotic Servicing of HST



Robotic Augmentation of EVA (from SM1)

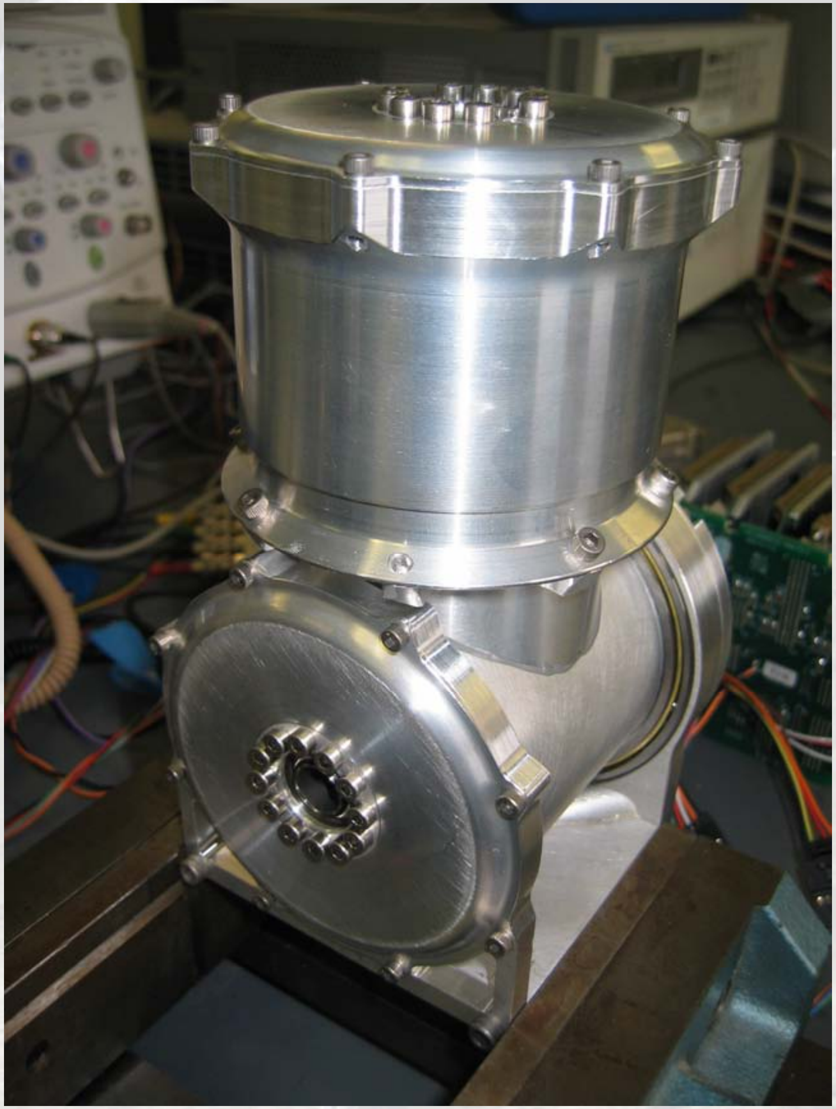


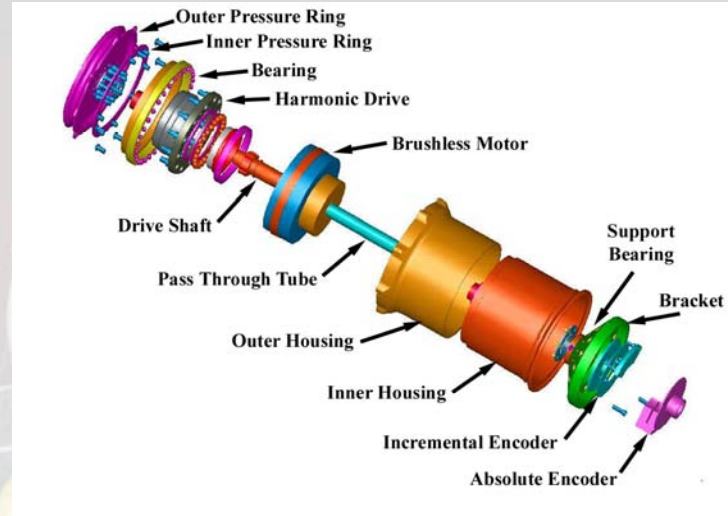
On-Orbit Servicing Demand by Types



Total Servicing Market ~$3-5B/year!

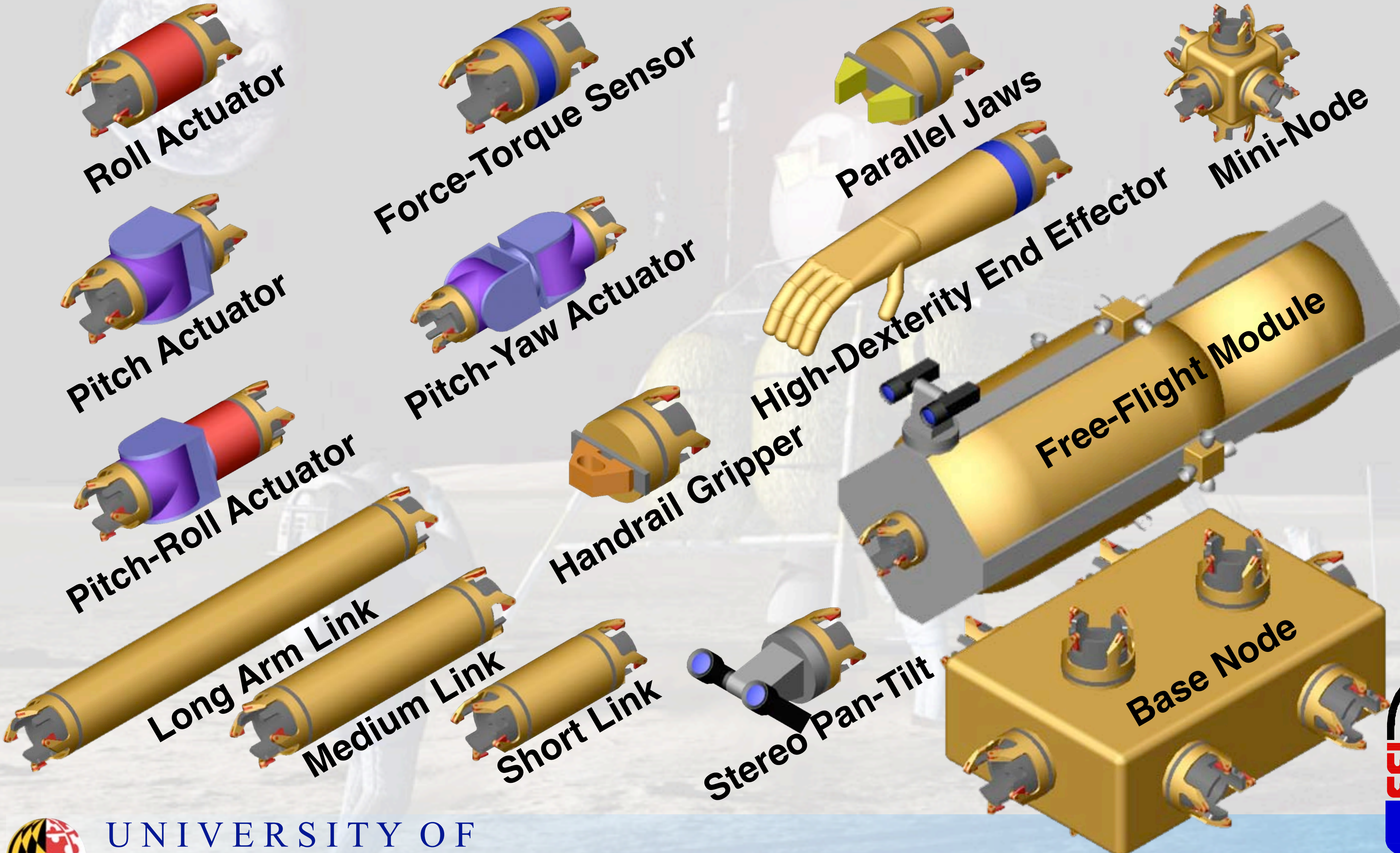
Proteus Actuator Technology





A Sample *Proteus* Toolbox

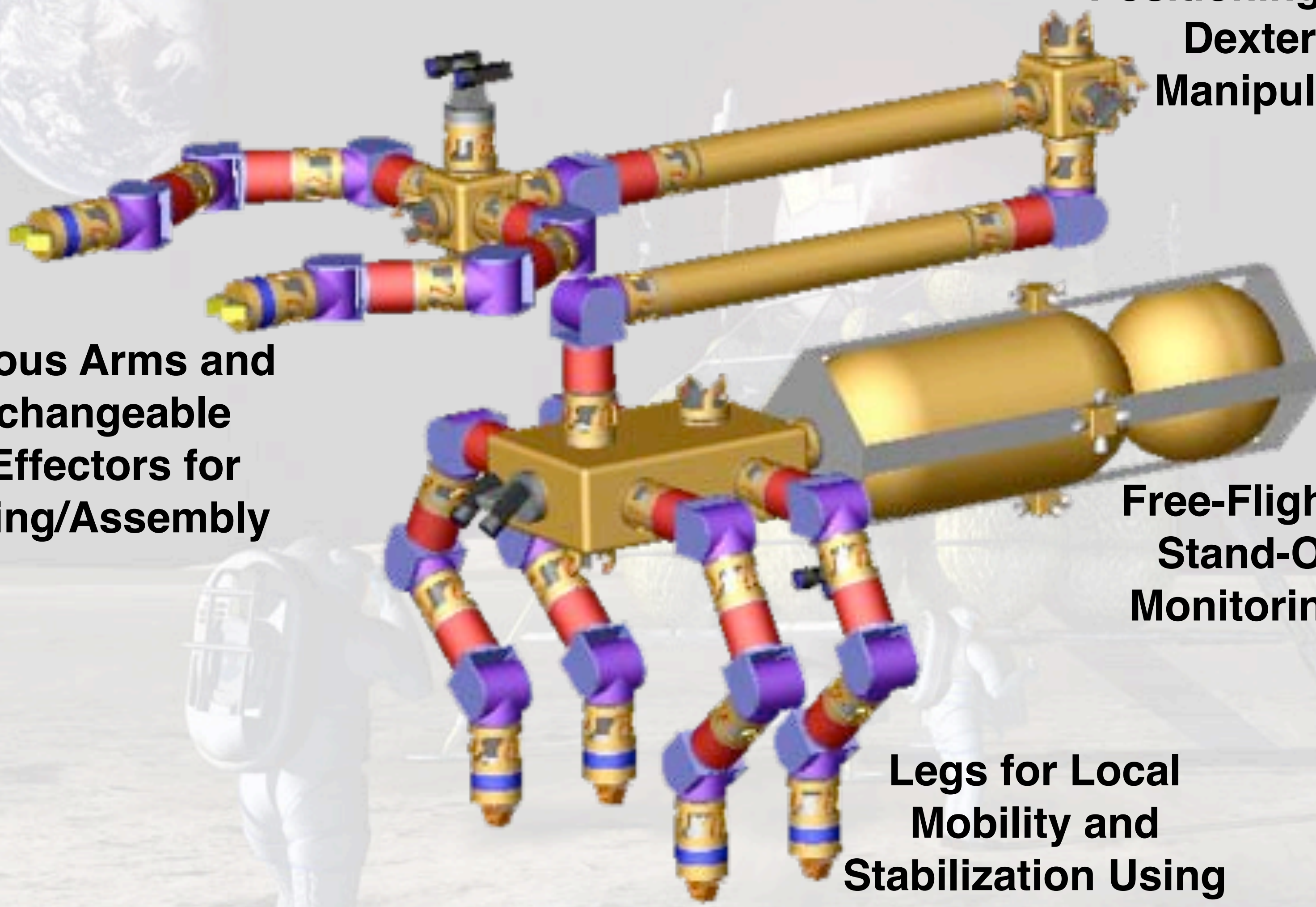
Modules | **End Effectors** | **Nodes**



A Potential *Proteus* Configuration

Positioning Arm for Dexterous Manipulators

Dexterous Arms and Interchangeable End Effectors for Servicing/Assembly

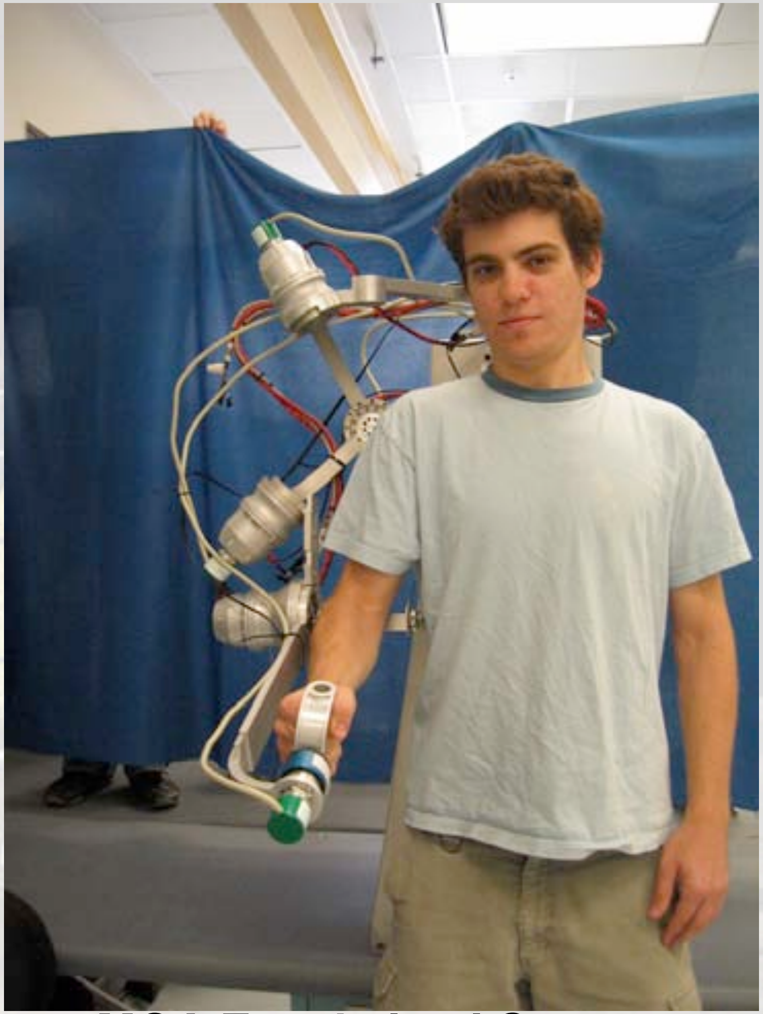


Free-Flight Module/ Stand-Off Video Monitoring Source

Legs for Local Mobility and Stabilization Using EVA Hand Rails

Current *Proteus*-Based Systems

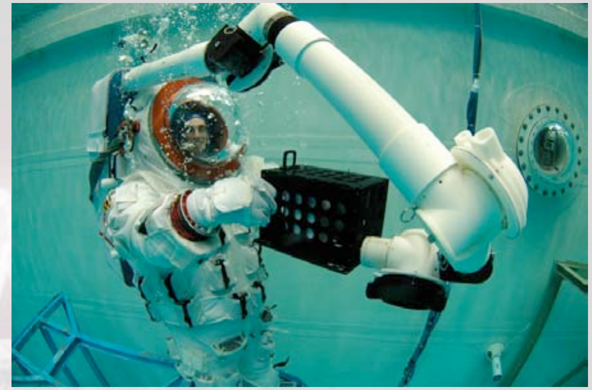
SAMURAI Deep-Submergence Manipulator



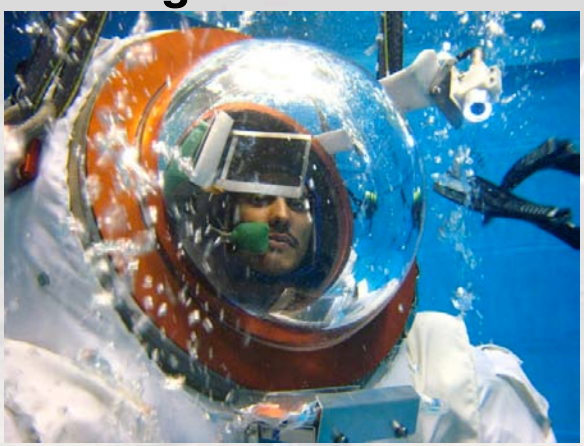
MGA Exoskeletal System for Shoulder Rehabilitation

Advanced Robot-Integrated Suits

Robot-Augmented Suit Gloves



Suit-Mounted Manipulators

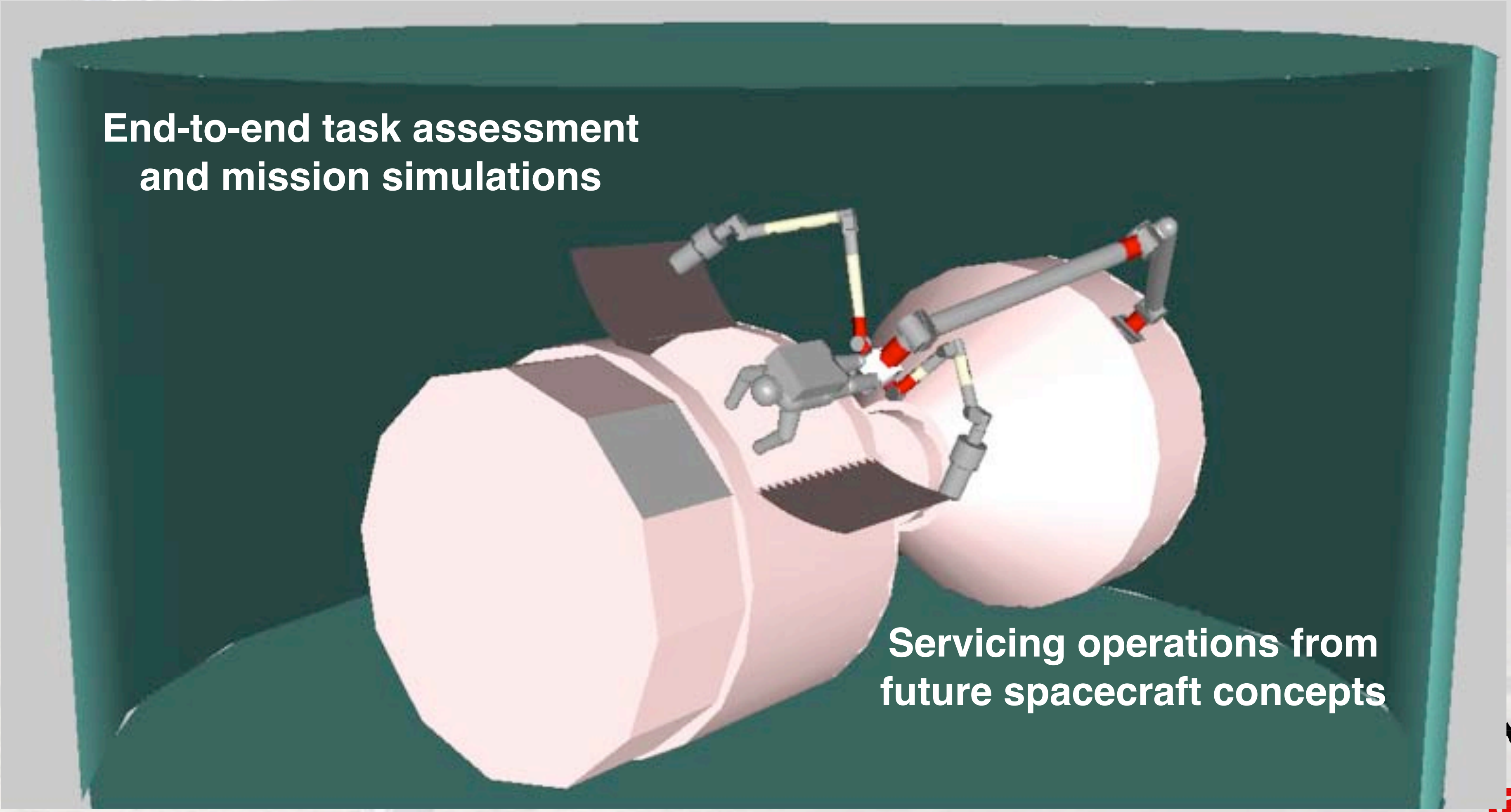


Advanced Controls and Displays

Morphing Space Suits

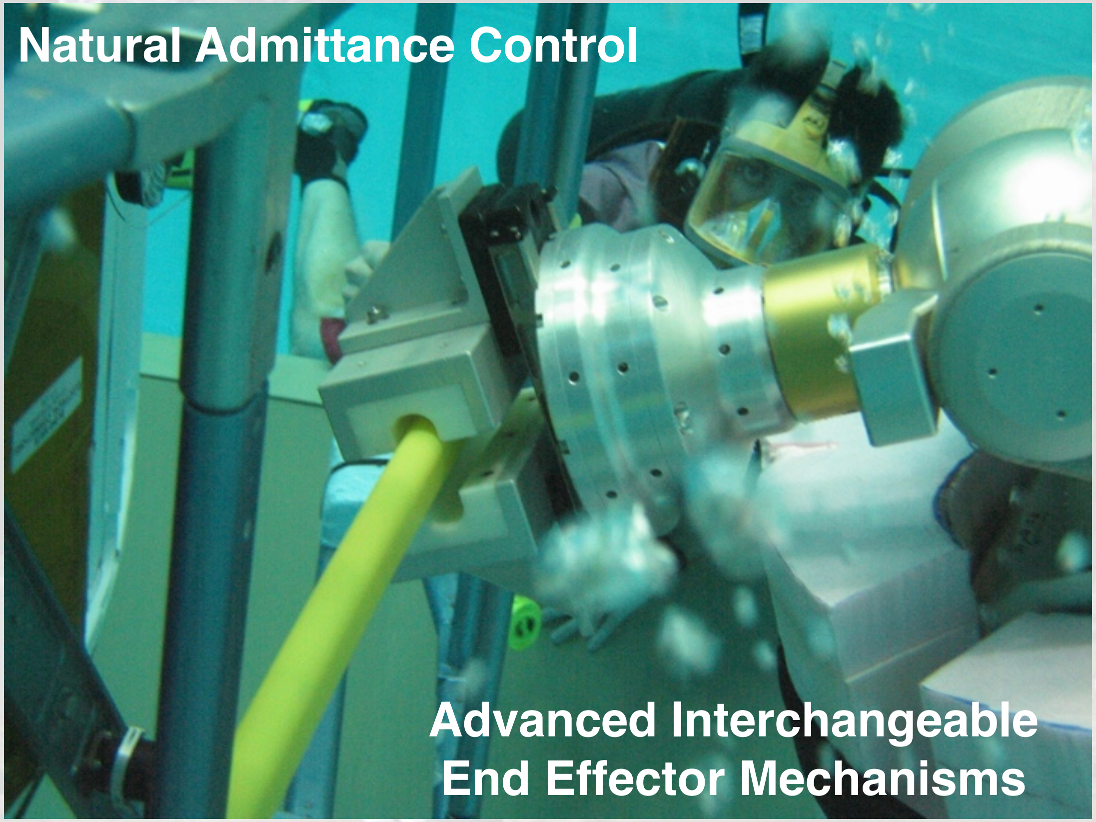
UMd Voice Command of GSFC RMS

NB Simulation of EVA/Robotic Servicing



Advanced Technologies for Servicing

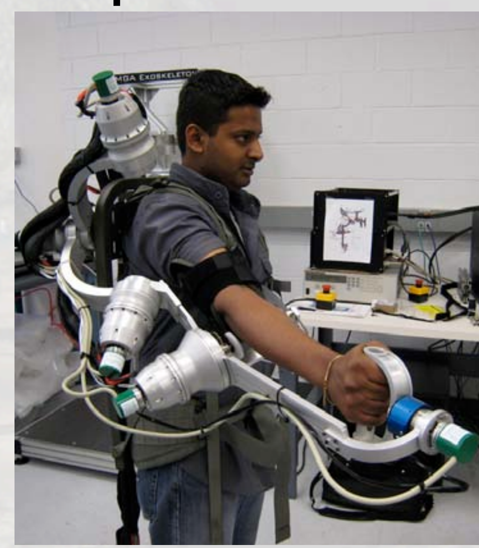
Lightweight Manipulator Actuators and Sensors



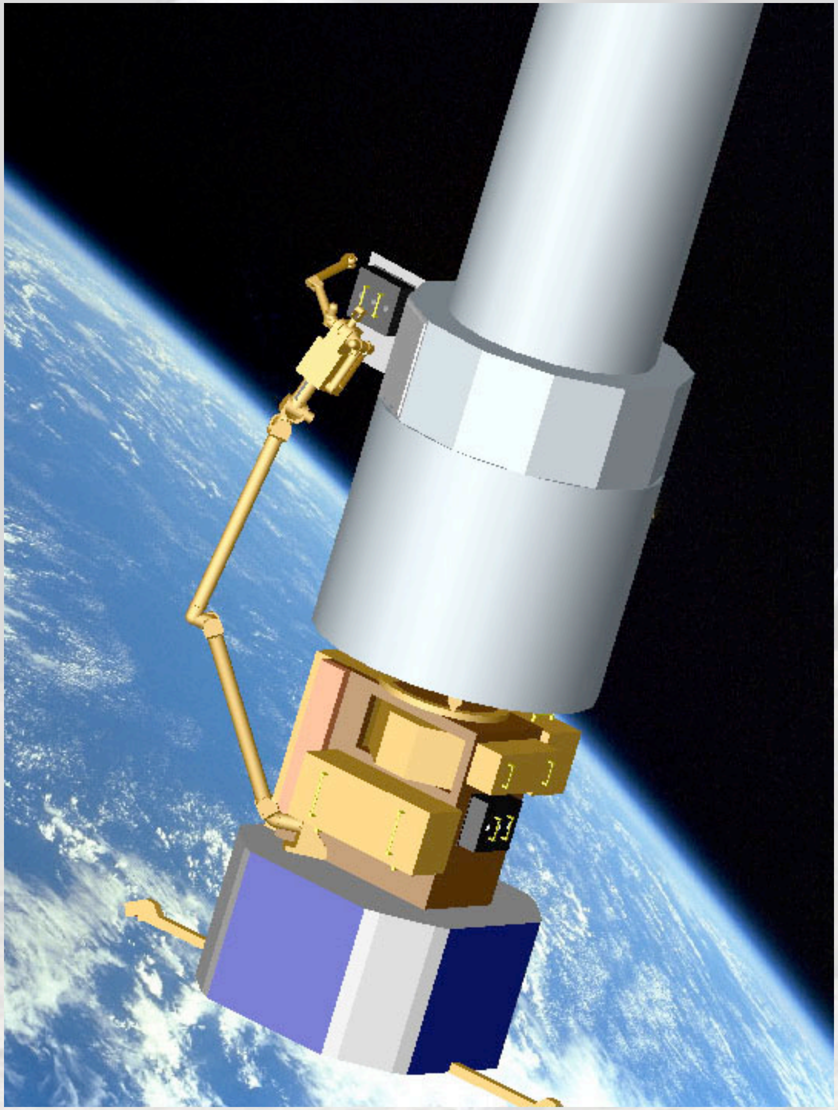
Adaptive Nonlinear Control Algorithms for Manipulator Motion

Advanced Mitigation of Time Delays

Full Haptic Control Station

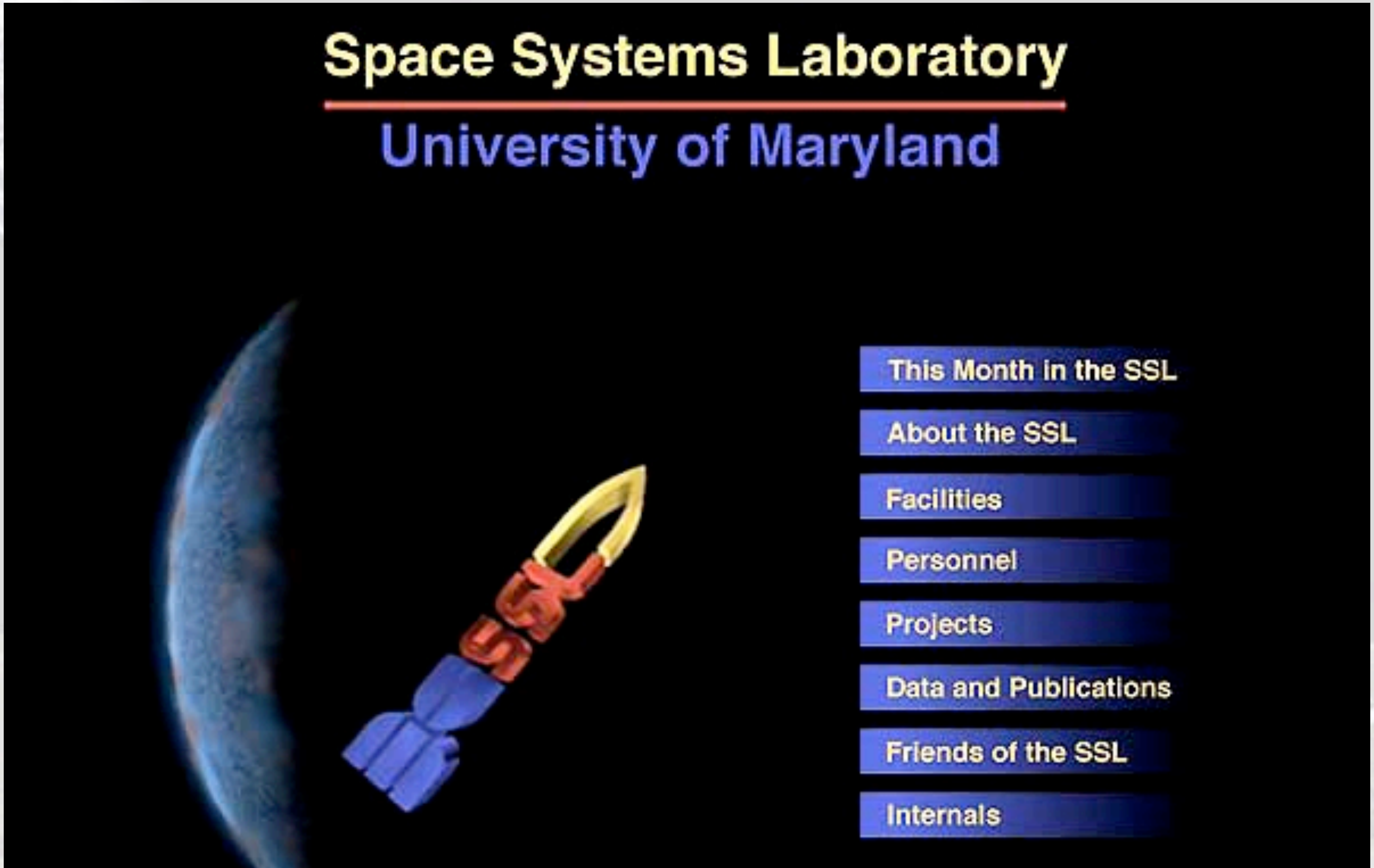


The Ultimate Robotic Flight Experiment



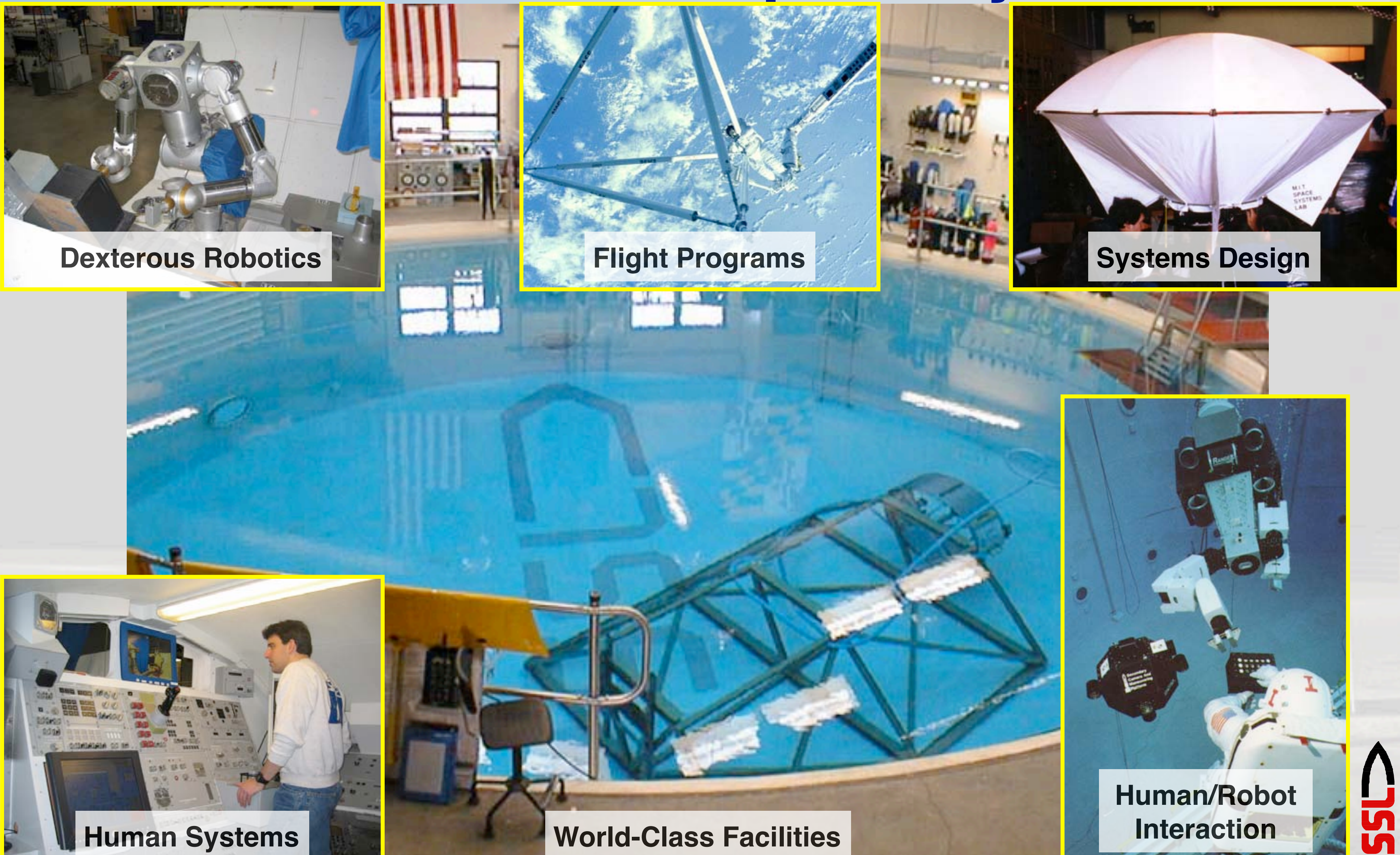
- At some point, the Hubble science mission will end
- Lightweight robotic servicer could be added to deorbit mission
- On-orbit robotic HST servicing will leverage decades of experience in EVA servicing and demonstrate robotic capabilities

For More Information

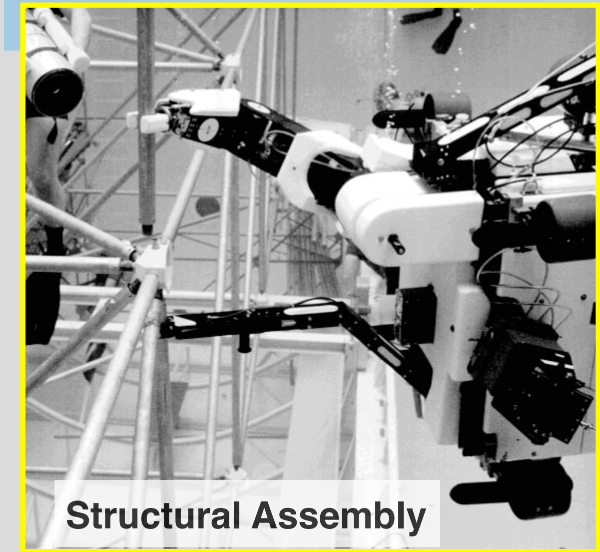


http://www.ssl.umd.edu
dakin@ssl.umd.edu

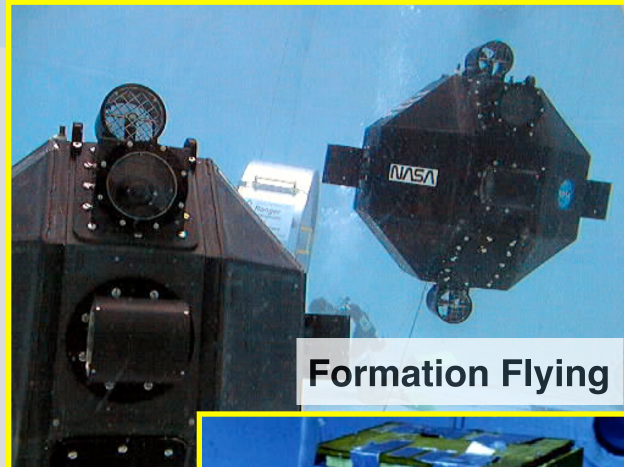
Overview of the UMd Space Systems Lab



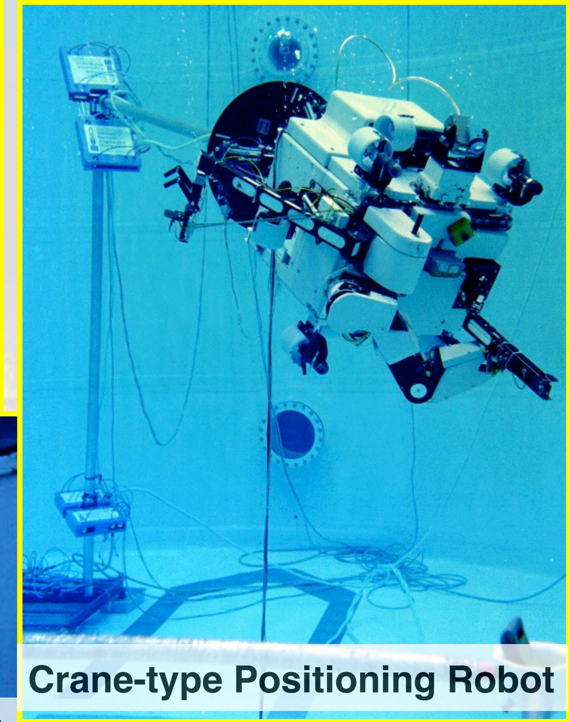
SSL Background in Space Robotics



Structural Assembly

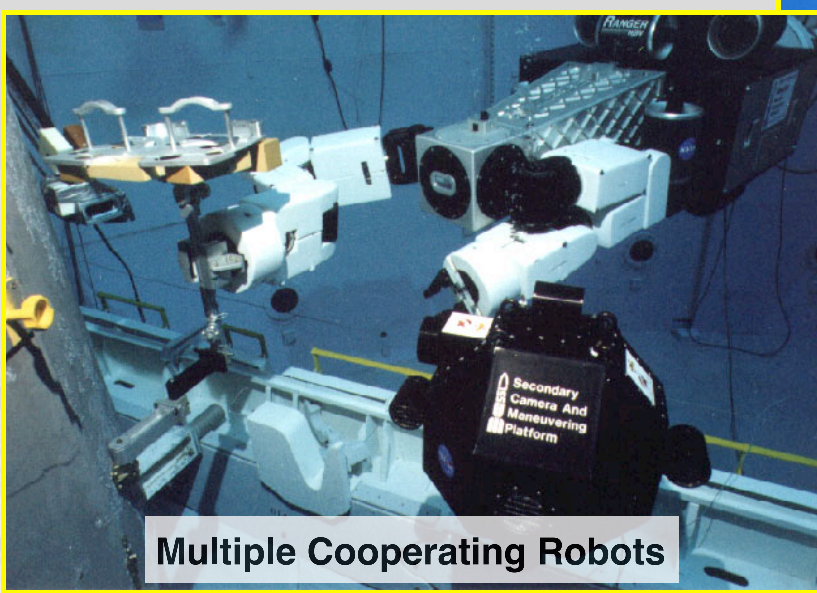


Formation Flying

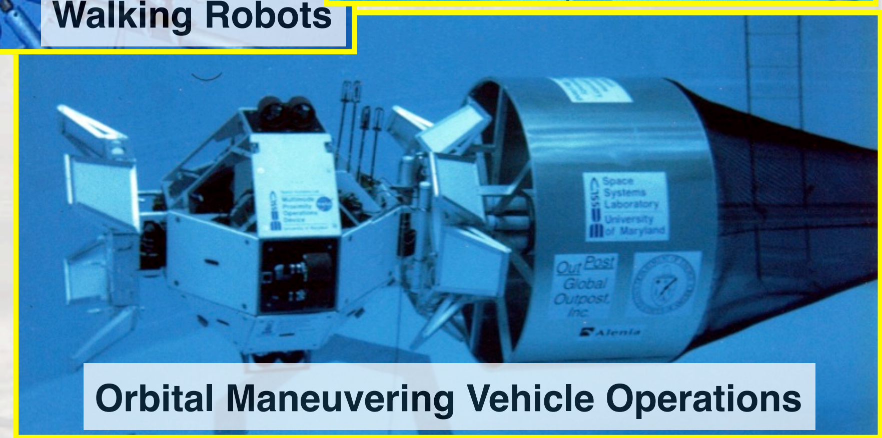


Crane-type Positioning Robot

Walking Robots



Multiple Cooperating Robots



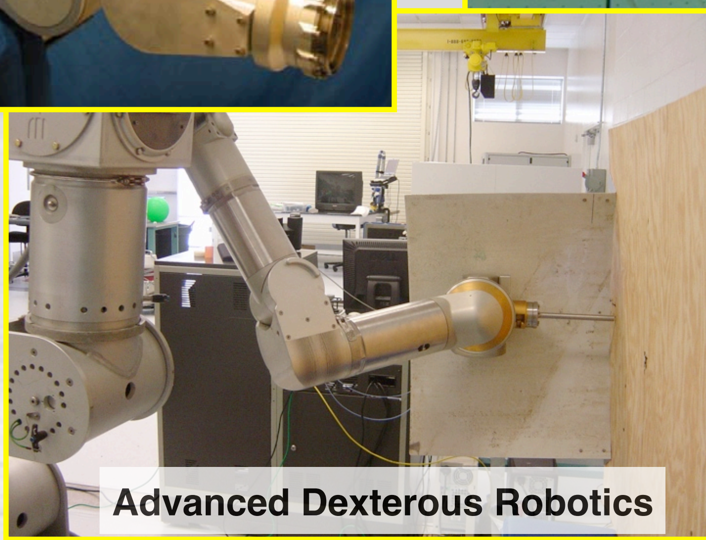
Orbital Maneuvering Vehicle Operations

Current Robotics Projects

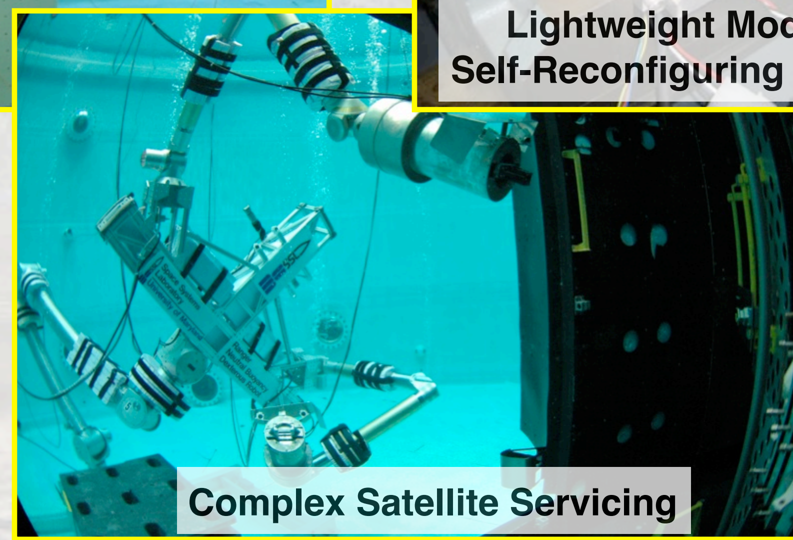
Autonomous Deep Submergence Manipulators

Free-Flying Inspection and Light Transport Robots

Lightweight Modular Self-Reconfiguring Robots



Advanced Dexterous Robotics

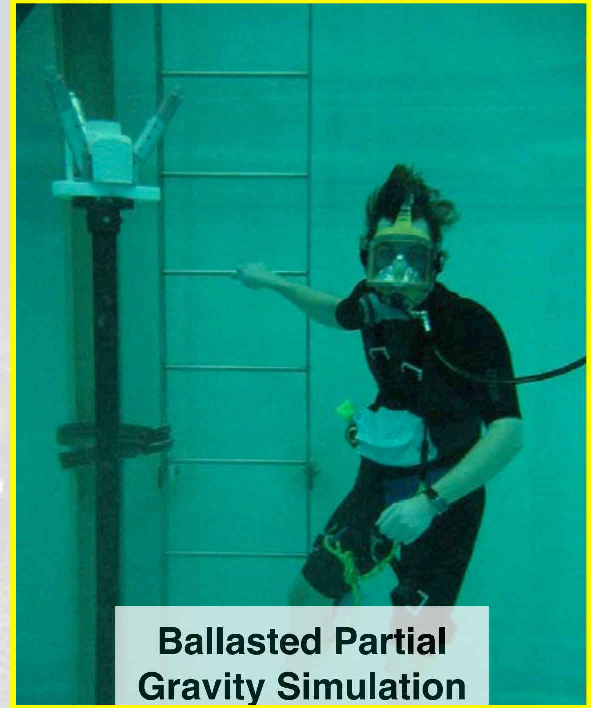


Complex Satellite Servicing

Current Human Systems Projects

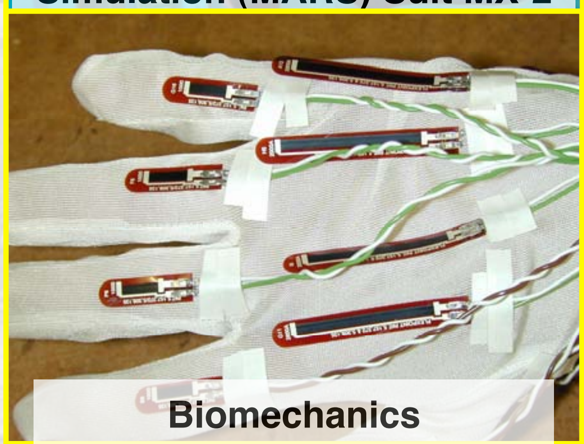
In-Suit Metabolic Workload

Maryland Advanced Research/ Simulation (MARS) Suit MX-2



Ballasted Partial Gravity Simulation

Advanced Life Support Systems

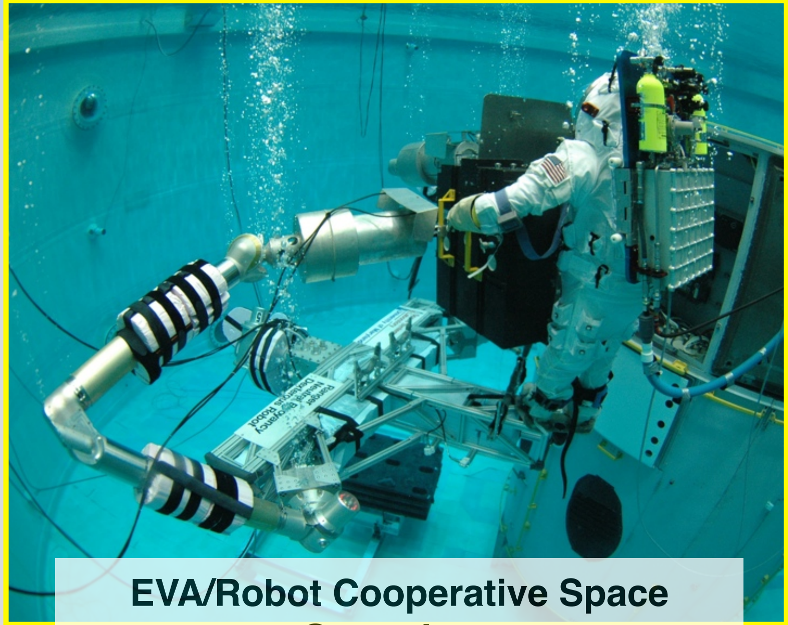


Biomechanics Instrumentation

Advanced Space Suit Gloves

Human/Robot Interaction Projects

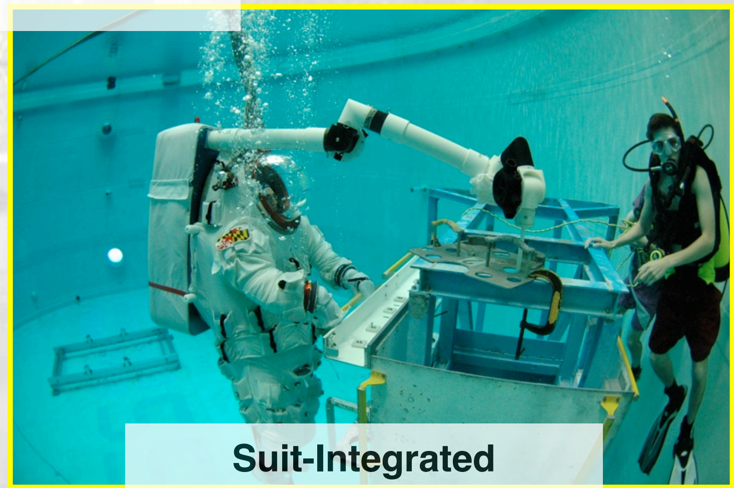
Morphing Space Suit Components



EVA/Robot Cooperative Space Operations

Exoskeleton Shoulder Rehabilitation Robot

Power-Assisted Space Suit Components



Suit-Integrated Manipulators

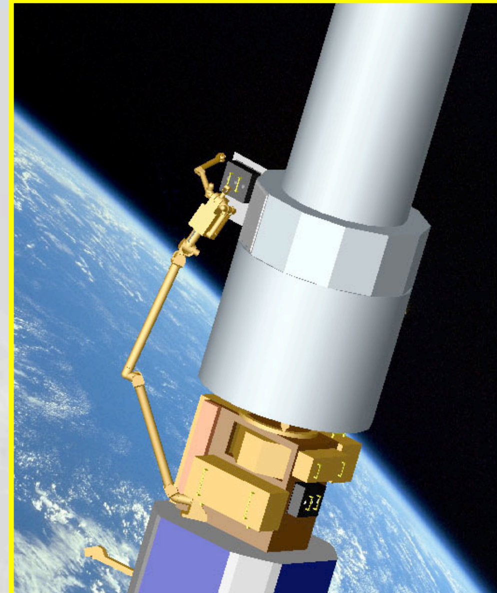
Approved for public release; distribution unlimited

Space Systems Design Activities


Advanced Human/Robot Systems


Transportation and Landing Systems


Orbital Habitats


Robotic HST Servicing


Full-Scale Mockups for Human Testing


Lunar and Mars Rovers


Planetary Surface Habitats

Space Systems Lab Facilities

Space Suit Development Lab

Flight Robotics Simulation Facility

Planetary Surface Mobility Simulator

Neutral Buoyancy Research Facility

Advanced Robotics Development Lab

Inspection and Secure Storage Lab

Flight Electronics Fab & Test Lab